

DUAL ENERGIZED HYDROSEAL**CROSS REFERENCE**

[0001] This is a Continuation-in-Part of Application Serial Number 10/017,097 filed December 24, 2001 and entitled Dual Energized Hydroseal.

BACKGROUND OF THE INVENTION**1. Field of the Invention.**

[0002] The present seal assembly will function when pressured acts on it from two different directions. It is therefore sometimes referred to as a bi-directional seal or a dual energized hydroseal. The present invention can be used in a variety of different types of valves where a dual energized seal assembly is needed, as well as in cases where single-direction control is necessary.

2. Background of the Invention.

[0003] The dual energized hydroseal includes a seal spool, two O-rings and two opposing seal cups. This bi-directional seal assembly can be used in a dirty fluid valve and a variety of other applications where a bi-directional seal assembly is needed, as well as in cases where a single direction seal assembly is necessary. For purposes of example, the dual energized hydroseal will be described in a dirty fluid valve, which is a type of cartridge valve frequently used in downhole tools. A plurality of dirty fluid valves are positioned in a downhole tool that is used for sampling wellbore fluids. A plurality of empty sample collection bottles are located in the downhole tool. When the tool is inserted in the wellbore, all of the dirty fluid valves are in the closed position as shown in Fig. 1. When the downhole tool reaches a depth that needs to be sampled, a pilot valve is pulsed, causing the seal carrier to slide the dual energized hydroseal assembly along opposing



seal plates and open the supply port, as shown in Fig. 2. This allows wellbore fluids to enter the supply port of the dirty fluid valve and move through the longitudinal passageway of the valve and out the function port to a sample collection bottle. A plurality of sample collection bottles are often included in a single tool so that the wellbore may be sampled at different depths.

[0004] External pressures in a wellbore often exceed 20,000 psi absolute. After a sample has been collected, a pilot valve is pulsed, causing the seal carrier to move back to the close position as shown in Fig. 1. The pressure inside the sample collection bottle is the same as the pressure in the wellbore at the collection depth. As the downhole tool is brought back to the surface, external pressure drops to standard atmospheric pressure, but the pressure inside the sample collection bottle remains at wellbore pressure, which may be in excess of 20,000 psi absolute.

[0005] The present seal assembly will function when pressure acts on it from two different directions. The present invention can be used in a variety of different types of valves. When the seal assembly of the present invention is constructed, the O-rings are squeezed into position and/or compressed approximately 40%. The squeeze of the O-rings causes them to act as springs urging the seal cups into contact with the opposing seal plates. By contrast, O-ring manufacturers such as Parker generally recommend that O-rings be squeezed axially approximately 20%-30% for static seal designs. The present invention is a static seal design. Other O-ring manufacturers, such as Apple, recommend that O-rings be squeezed axially for static seal in the range of approximately 25%-38%. Squeezing the O-rings more than recommended by most manufacturers improves the function in the present invention. The O-rings in the present invention perform a dual function as both the spring and the seal. They act as a spring to force the seal cups into contact with the opposing seal plates, at lower pressures and they act as a seal at higher pressures.

[0006] The present invention is rated to operate up to 30,000 psi and 350° F. Gilmore Valve Co., the assignee of the present invention, has previously produced a dirty fluid valve with a bi-directional seal that was rated to operate up to 20,000 psi absolute and 250° F (see Gilmore Valve Co. drawing No. 25082, a copy of which is enclosed in the Informational Disclosure Statement which is filed concurrently herewith). The present invention uses two compressed O-rings to energize the bi-directional seal. The prior art dirty fluid valve from Gilmore Valve Co. used only one O-ring to energize a bi-directional seal. The prior art O-ring used by Gilmore Valve Co. in the dirty fluid valve shown in drawing No. 25082 was produced by Greene Tweed of Houston, Texas from Viton ® 90 durometer anti-explosive decompressive material. The present invention uses two O-rings produced from Buna-N 90 durometer material. Applicants have determined that a Parker No. 2-004 O-ring is suitable for use in the present invention. The Viton of the prior art is relatively stiff and the Buna-N of the present invention is more resilient. Buna-N has more of a memory and therefore works better than the Viton as a spring. The prior art Gilmore Valve Co. seal, described in drawing No. 25082, although it was bi-directional, loses sealing integrity at operational pressures in excess of 25,000 psi. The present invention is rated to operate up to 30,000 psi. The present invention functions at higher operational pressures because there are two O-rings instead of one, the O-ring material is different than the prior art, the mechanical and hydraulic sealing forces are improved, and the present seal design is less complicated.

[0007] U.S. Patent No. 5,662,166 to Shammai, discloses an apparatus for maintaining at least downhole pressure of a fluid sample of upon retrieval from an earthbore. The Shammai device has a much more complex series of seal than the present invention. Further, the Shammi device does not have a dual-energized seal like the present invention.

[0008] U.S. Patent No. 5,337,822 issued to Massie *et al.*, discloses a wellfluid sampling tool.

The Massie device maintains samples at the pressure at which they are obtained until they can be analyzed. The device does not, however, maintain this pressure by means of a dual-energized hydroseal. Rather, the device of Massey uses a hydraulically driven floating piston, powered by high-pressured gas such as nitrogen acting on another floating piston, to maintain sample pressure.

SUMMARY OF THE INVENTION

[0009] The seal assembly of the present invention uses two O-rings that are squeezed more than 38.5% causing them to act as springs urging the seal cups into sealing engagement at very low pressures with the seal plates and as seals at higher pressures. At higher pressure a seal is achieved because pressure on the rear of the seal cups forces them into sealing engagement with the opposing seal plates. The pressure forces act on the seal cups to achieve a tight metal to metal seal. The bi-directional seal assembly of the present invention is shown in a dirty fluid valve which is positioned in a downhole tool for sampling wellbore fluids. The seal assembly of the present invention can be used in a variety of other types of valves that require bi-directional seal assemblies and in other types of valves that only require a uni-directional seal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a section view of a valve with the dual energized hydroseal. The valve is in the closed position in an unpressurized state.

[0011] Fig. 2 is a section view of the valve of Fig. 1 except the valve is in the open position and

Fluid is shown flowing through the valve by the flow arrows.

- [0012] Fig. 3 is a perspective view of the seal spool.
- [0013] Fig. 4 is an enlarged section view of the seal spool and O-rings in a relaxed position.
- [0014] Fig. 5 is a perspective view of one seal cup.
- [0015] Fig. 6 is an enlarged cross sectional view of one seal cup.
- [0016] Fig. 7 is an enlarged cross sectional view of the dual energized hydroseal exposed to supply pressure.
- [0017] Fig. 8 is an enlarged cross sectional view of the dual energized hydroseal exposed to function pressure.
- [0018] Fig. 9 is a sectional view of a valve with an alternative embodiment of the dual energized hydroseal. The valve is in the closed position in an unpressurized state.
- [0019] Fig. 10 is an enlarged sectional view of a valve with an alternate embodiment of the dual energized hydroseal showing details of an alternate O-ring seal arrangement.
- [0020] Fig. 11 is an enlarged sectional view of a portion of the valve showing the dual energized hydroseal exposed to supply pressure with the valve in a closed position.
- [0021] Fig. 12 is an enlarged sectional view of the dual energized hydroseal showing the O-ring seals in an outward position as seen in Fig. 11 with the fluid pressure being applied on their inner perimeter.
- [0022] Fig. 13 is an enlarged sectional view of a valve showing the O-ring seals compressed to an inner position with the fluid pressure being applied to the O-rings on their outer perimeter.
- [0023] Fig. 14 is an enlarged perspective view of an outer seal back-up ring.
- [0024] Fig. 15 is an enlarged perspective view of an inner seal back-up ring.

DESCRIPTION OF THE INVENTION

[0025] Referring to Fig. 1, the dirty fluid valve is generally identified by the numeral 10. The valve 10 is a normally closed, two position, two-way valve. The valve 10 is sometimes referred to as a “cartridge” type valve, because it is often manufactured in the configuration of Fig. 1 and it is slipped into a valve chamber in the body of a downhole tool. The downhole tool typically have – or more dirty fluid valves, to test wellbore fluids at different well depths. Each valve 10 is in fluid communication with the wellbore and a sample collection bottle to hold wellbore fluids. The valve 10 is typically rated for operational pressures of up to 30,000 psi and temperatures of up to 350°F.

[0026] The valve 10 has a generally cylindrical body 12 which defines a longitudinal bore 14 which is sized and arranged to receive a seal carrier 16. The seal carrier moves from a normally closed position shown in Fig. 1 to an open position shown in Fig. 2.

[0027] The body 12 has threads 18 formed on one end to threadably engage the cap 20. A cylinder cover 22 surrounds a portion of the body 12. The cylinder cover 22 is rotationally held in place on the body by a set screw 24 and longitudinally in place by cap 20.

[0028] The body 12 defines an open pilot port 26 which is in fluid communication with an open chamber 28. The body 12 and the cylinder cover 22 define a close pilot port 30 which is in fluid communication with the close chamber 32 which is defined by the longitudinal bore 14 in body 12, the cap 20 and the seal carries 16. The open pilot port 26 is in fluid communication with a pilot open valve, not shown. The close pilot port 30 is in fluid communication with a pilot close valve, not shown. Both pilot valves are connected to a source of pressurized pilot fluid, not shown.

[0029] The seal carrier 16 has a transverse bore 34 sized and arranged to receive a bi-directional seal assembly generally identified by the numeral 36. A transverse flow passageway 38 is also formed in the seal carrier 16 to facilitate fluid flow through the valve when it is in the open position.

[0030] A bore 40 is formed in the body 12 and is sized and arranged to receive the first seal plate 42. A through bore 44 is formed in the seal plate 42 and is in fluid communication with a supply port 46 formed in the cylinder cover 22.

[0031] A bore 48 is formed in the body 12 and is sized and arranged to receive the second seal plate 50. A through bore 52 is formed in the seal plate 50 and is in fluid communication with a supply port 54 formed in the cylinder cover 22. For purposes of claim interpretation, the body 12 and the cylinder cover 22 may collectively be referred to as the body, although for manufacturing convenience, they are produced as two separate parts.

[0032] When the downhole tool is placed in the wellbore, pressures may reach 30,000 psi, depending on the depth of the well. Wellbore fluids exert this “supply pressure” as indicated by the arrow in Fig. 1.

[0033] To shift the valve 10 from the closed position of Fig. 1 to the open position of Fig. 2, the pilot open valve is actuated allowing pilot pressure to enter the open port 26 and the open chamber 28. The force of the pressurized pilot fluid acting on the seal carrier 16 shifts it to the open position of Fig. 2.

[0034] Referring to Fig. 2, the valve 10 is shown in the open position. Wellbore fluids indicated by the flow arrows, pass through the open ports 46 and 54 of the cylinder cover 22 and the through bore 44 and 52 of seal plates 42 and 50. The wellbore fluids then pass through the flow passageway 38 in the seal carrier 16, the longitudinal bore 14 and out the function ports 56 and

58, as indicated by the flow arrows, to the sample collection bottle, not shown. After the sample has been taken, the pilot close valve is actuated and pressurized pilot fluid enters the close port 30 and the close chamber 32. The pilot fluid is typically pressurized in the range of 1,500 to 10,000 psi. The force of this pilot fluid on the seal carrier causes it to shift from the open position of Fig. 2 to the closed position of Fig. 1. A spring 102 is positioned in the close chamber 32. A typical spring rate for the valve 10 is 261 lb./in. The spring 102 urges the seal carrier 16 into the normally closed position of Fig. 1.

[0035] An O-ring groove 104 is formed in the cap 20 and is sized and arranged to receive O-ring 106 which seals the cap 20 against the valve chamber in the downhole tool. A groove 108 is formed in the cylinder cover 22 and is sized and arranged to receive T-seal 110 which seals the cylinder cover 22 against the valve chamber in the downhole tool.

[0036] A groove 112 is formed in the body 12 and is sized and arranged to receive T-seal 114. A groove 116 is formed in the body 12 and is sized and arranged to receive T-seal 118. A groove 120 is formed in the body 12 and is sized and arranged to receive T-seal 122. T-seals 114 and 118 seal and isolate the function port 56 against the valve chamber in the downhole tool, not shown. T-seals 118 and 122 seal and isolate the pilot open port against the valve chamber in the downhole tool, not shown.

[0037] A groove 124 is formed in the seal carrier 16 and is sized and received to receive an O-ring 126 and a lock-up ring 128. The O-ring 126 and backup ring 128 seal and isolate the open chamber 28 from the other flow passageways in the valve 10.

[0038] A groove 130 is found in the other end of the seal carrier 16 and is sized and arranged to receive an O-ring 132 and backup ring 134. The O-ring 132 and backup ring 134 seal and isolate the close chamber 32 from the other flow passageways in the valve 10.

[0039] The bi-directional seal assembly generally identified by the numeral 36 is positioned in the transverse bore 36 of seal carrier 16. The seal assembly functions when supply pressure (pressure from wellbore fluids) enters the through bore 44 of first seal plate 42 and the through bore 52 of seal plate 50 and is applied to the seal assembly 36. The seal assembly also functions when function pressure (from the sample collection bottle) enters the longitudinal bore 14, and the transverse bore 34 in the seal carrier 16 and is applied to the seal assembly 36. The seal assembly 36 is therefore referred to as “bi-directional” because it functions when exposed to both supply pressure (pressure from wellbore fluids in the well) and function pressure (pressure from the stored wellbore fluids in the sample collection bottle).

[0040] The seal assembly 36 includes a first seal cup 160, a second seal cup 162, a seal spool 164, a first O-ring 166 and a second O-ring 168.

[0041] Referring to Fig. 3, the seal spool 164 is shown in perspective view. The seal spool 164 has a central axle 200 bisected by a circular collar 202. The axle 200 has a first end 204 and a second opposing end 206.

[0042] Referring to Fig. 4, the seal spool 164 is shown in section view with two O-rings 166 and 168. The O-ring 166 fits on the first end 204 of axle 200 and the second O-ring 168 fits on the second end 206 of the axle 200. The circular collar 202 is formed on an angle of approximately 10°. However, a 90° angle between the collar 202 and the axle 200 also functions satisfactorily.

[0043] O-rings are used in two basic applications generally referred to as “static” and “dynamic” by those skilled in the art. The O-rings 166 and 168 in the bi-directional seal assembly 36 are considered as static. In a static seal, the mating gland parts are not subject to relative movement. In the present invention, the transverse bore 34, the seal spool 164, and the seal cups 160 and 162 are nonmoving.

[0044] O-ring manufacturers, for example Parker Seals of Parker Hannifin Corp. of Lexington, Kentucky, generally recommend that some squeeze be applied to O-rings for maximum sealing effectiveness. Squeeze can be either axial or radial. The O-rings 166 and 168 shown in Fig. 4 are in a relaxed state. However, when placed in the seal assembly 36 in the transverse bore 34, the O-rings are typically squeezed axially more than the amount typically recommended by O-ring manufacturers.

[0045] In the present invention, a Parker No. 2-004 O-ring is suitable for use as O-rings 166 and 168. These O-rings are formed from Buna-N 90 durometer material and the maximum operational temperature suggested by Parker is 350° F. Applicants recommend an axial squeeze of 40% or more. The July 1999 Parker O-ring Handbook Design Chart 4-2, a copy of which is included in the Information Disclosure Statement, filed concurrently herewith recommends an axial squeeze for No. 2-004 through 050 of 19 to 32 percent. Design chart 4-2 is for static O-ring sealing. Other O-ring manufacturers, for example, Apple Rubber Products of Lancaster, New York, recommends an axial squeeze for an O-ring with a .070 cross-section of between 25.5 and 38.5 percent for a static seal. (See page 17 of the Apple Rubber Products Seal Design Catalog, portions of which are included in the Information Disclosure Statement filed concurrently herewith).

[0046] Referring to Fig. 5 and Fig. 6, the first seal cup 160 is shown. The first seal cup 160 has a through bore 220 a portion 222 of which is sized and arranged to receive the first end 204 of the axle 200 of seal spool 164. The seal cup 160 has a flat sealing surface 224 that seals against flat sealing surface 226 of first seal plate 42.

[0047] Referring to Fig. 7, an enlarged section view of the seal assembly 36 is shown. O-rings 166 and 168 are squeezed axially about 40% or more against the collar 202 by the seal cups 160

and 162. The second seal cup 162 has a flat sealing surface 228 formed thereon to seal against an opposing flat sealing surface 230 of seal plate 50. Seal cup 162 has a through bore 232, a portion 234 of which is sized and arranged to receive the second end 200 of the axle.

[0048] In Fig. 7, the arrows indicate supply pressure (from wellbore fluids) that passes through bore 44 in the seal plate 42 and bore 220 in first seal cup 160 urging O-ring 166 away from first axle portion 204 and against the transverse bore 34. Likewise supply pressure (from wellbore fluids) passes through bore 52 in seal plate 50 and bore 232 in second seal cup 162, urging O-ring 168 away from second axle portion 206 and against the transverse bore 34. As O-rings 166 and 168 deform against the id of the transverse bore, the supply pressure exerts force against the rear surface 240 of first seal cup 160 and the rear surface 242 of second seal cup 162. This supply pressure exerted on rear surfaces 240 and 242 creates a metal to metal seal between the seal cup 160 and seal plate 42 and seal cup 162 and seal plate 50.

[0049] After the valve 10 has been opened and wellbore fluids, sometimes at pressures as much as 20,000 psi are stored in the sample collection bottle, the downhole tool is removed from the hole. At the surface, pressure on the outside of the tool at seal level is one atmosphere, but the pressure in the sample collection bottle will still be at wellbore pressure, perhaps 20,000 psi. For this reason the seal assembly 36 must be bi-directional and be able to seal when function pressure from the sample collection bottle exceeds ambient pressures surrounding the downhole tool.

[0050] In Fig. 8, the arrows indicate function pressure (from the sample collection bottle) that passes through the longitudinal bore 14 and passes between the transverse bore 34 and first seal cup 160 and second seal cup 162, urging O-rings 166 and 168 into contact with axle portions 204 and 206 and away from transverse bore 34. As O-ring 166 and 168 deform against the id of the

axle portions 204 and 206, function pressure exerts force against the rear surface 240 of seal cup 160 and the rear surface 242 of seal cup 162. The function pressure exerted on rear surfaces 240 and 242 creates a metal-to-metal seal between the seal cup 160 and seal plate 42 and seal cup 162 and seal plate 50.

[0051] O-rings 166 and 168 are squeezed axially more than the amount recommended by the manufacturers because the O-rings 166 and 168 perform actual purpose. First, the O-rings 166 and 168 act as springs and second, they act as seals. At low pressures, it is important to ensure that first seal cup 160 engages first seal plate 42 at low pressures. Because O-ring 166 is squeezed axially, it exerts force against the seal cup 160 like a spring to ensure contact.

However, sealing between seal cup 160 and seal plate 42, at higher pressure, is due to forces exerted on the rear 240 of the seal cup 160 by either supply or function pressure.

[0052] Likewise it is important to ensure that second seal cup 162 engages second seal plate 50 at low pressures. Because O-ring 168 is squeezed axially, it exerts force against the seal cup 162 like a spring to ensure contact. However sealing between seal cup 162 and seal plate 50, at higher pressures, is due to forces exerted on the rear 242 of the seal cup 162 by either supply or function pressure.

[0053] In Figs. 7 and 8, seal cup 160 has a lip 250 that extends into the through bore 220.

Likewise seal cup 162 has a lip 252 that extends into through bore 254. In an alternative embodiment, the lips 250 and 252 are eliminated.

[0054] Fig. 9 is a section view of an alternative embodiment 254 of the seal assembly. The seal assembly 254 is the same as seal assembly 36, except first seal cup 256 and second seal cup 258 do not have lips 250 or 252. In all other respects, the seal assembly 254 functions in the same fashion as seal assembly 36.

[0054] Figs. 10-15 show an additional embodiment of the present invention which is similar in construction and operation to the valve embodiments disclosed above. Like numbers throughout the various figures designate like or similar parts that are described above. Because these parts are described above, those parts need not be described again herein. The embodiment shown in Figs. 10-15 show back-up rings 301 and 302 to provide additional support for the O-rings 166 and 168 carried by the seal spool 164. There are a pair of back-up rings 301 and 302 positioned at each end portion 204 and 206 of the axle 200. The rings 301, 302 are preferably made of PEEK (poly-ether-ether-ketone). The use of the back-up rings 301, 302 permit the valve to be operated at higher pressures and temperatures than valves without the back-up rings. The collar 202 separates the two O-rings, 166 and 168. The rings 301 are outer positioned rings and the rings 302 are inner positioned rings. The pair of rings 302 are each positioned adjacent a respective end portion 204, 206 of the spool 200. These rings engage the outer perimeter or surface of axle 200 and have a first surface 310 for engagement with a respective surface 240 or 242 of the respective seal cup 160 or 162. The rings 302 also have a surface 312 which is generally cylindrical and is in engagement with an exterior surface or outer perimeter of the axle 200. A third surface 314 extends between ends of the surfaces 310 and 312 providing a surface for engagement with the respective O-ring 166, 168 at least when the O-rings are in the position shown in Fig. 13 when the valve is open. The rings 302 prevent the O-rings 166, 168 from flowing or deforming (extruding) into the space between the seal cup 160, 162 and the respective end portions of the axle 200. The rings 302 are positioned around and in contact with the first and second end portions 204, 206 of the axle 200, 204, 206 between the respective seal cup 160, 162 and the respective O-ring.

[0055] The back-up rings 301 are generally triangularly shaped, having surfaces 320 for engagement with the respective surface 240, 242 of the seal cups 160, 162, respectively. Each of the rings 301 has a second surface 322 for engagement with the surface defining the bore 34. The rings 302 thereby bridge the gap between the seal carrier 16 and the respective seal cups 160, 162. When an O-ring 166, 168 is pressurized or its inner perimeter is moved to an outer or expanded condition as shown in Fig. 11. The use of the rings 301 prevent the O-ring from flowing or deforming (extruding) into the gap between the surface defining the bore 34 and the outer perimeter of the seal cups 160 and 162. The rings 301 have a third surface 324 for engagement with the outer surface of the respective O-ring 166, 168.

[0056] Each of the O-rings 166, 168 is compressed axially by its respective seal cup 160 and 162 and their respective pair of back-up rings 301, 302 against the collar 202. The collar 202 has generally oppositely facing surfaces that engage the O-rings. The surfaces of the collar 202 engaging the O-rings may be generally normal (0°) to the longitudinal axis of the axle 200 or may be inclined toward the center of the collar 202 at an angle of up to 10° . When the O-rings are compressed between the respective seal cup and collar 202 and their respective back-up rings 301 and 302, the O-rings act not only as seals but as springs urging the seal cups 160, 162 into contact with the opposing seal plates 42 and 52.

[0057] The O-rings 166, 168 move radially inwardly and outwardly depending upon the source of pressure. When the source of pressure is in the direction of the arrows seen in Fig. 11 the O-rings move to an outward or expanded position. When the pressure is applied in the direction of the arrows in Fig. 13, the O-rings 166, 168 move inwardly to engage the axle 200. Preferably, there is some clearance provided so that the seal plates 42, 52 and seal cups 160, 162 can move

inwardly. The seal plates 42 and 52 are provided with T-heads that engage a shoulder to prevent excessive inward movement and over-compression or pressurization of the O-rings 166 and 168.

[0058] When the seal assembly is exposed to supply pressure, as discussed above, and as seen in Fig. 11, the seal cups 160, 162 energize the respective O-ring forcing it out of contact with the axle and into sealing contact with the surface defining the transverse bore 34 of the seal carrier so supply pressure can force both the seal cups into sealing engagement with the seal plates.

When the seal assembly is exposed to function pressure as seen in Fig. 13, the function pressure enters the transverse bore 34 of the seal carrier energizing the O-rings, forcing them out of contact with the surface defining the transverse bore 43 and into sealing contact with the seal spool 164, the axle 200, the rings 302 and the seal cups 160, 162, so the function pressure can force both seal cups into sealing contact with the seal plates, as disclosed above. To effect sealing, the O-rings are squeezed axially more than 38.5% between the collar and the seal cups.

[0059] Thus, the seal arrangement shown in the embodiment of Figs. 10-15, and notably that shown specifically in Fig. 10, replaces the seal arrangement shown in Figs. 1-9, and more specifically, for example, that shown in Fig. 4.